AD NUMBER
AD869214
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 30 APR 1970. Other requests shall be referred to Department of the Air Force, Attn: Public Affairs Office, Washington, DC 20330.**
AUTHORITY
USAF ltr 25 Jan 1972


1.0
4.5
5.0
5.6
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

TECHNICAL REPORT NO. 70-17

DEVELOPMENT OF LP WAVE DISCRIMINATION CAPABILITY USING LP STRAIN INSTRUMENTS

QUARTERLY REPORT NO. 7

PROJECT VT/8706

SPONSORED BY

ADVANCED RESEARCH PROJECTS AGENCY
NUCLEAR TEST DETECTION OFFICE
ARPA ORDER NO. 624

AVAILABILITY

ACKNOWLEDGMENT

NOTICE

TELEDYNE GEOTECH

TECHNICAL REPORT NO. 70-17

DEVELOPMENT OF LP WAVE DISCRIMINATION CAPABILITY USING LP STRAIN INSTRUMENTS

Quarterly Report No. 7, Project VT/8706

by

James E. Fix

Sponsored by

Advanced Research Projects Agency
Nuclear Test Detection Office
ARPA Order No. 624

Availability

Qualified users may request copies of this document from:

Defense Documentation Center
Cameron Station
Alexandria, Virignia 22314

Acknowledgement

This research was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, under Project VELA-UNIFORM, and accomplished under the technical direction of the Air Force Technical Applications Center under Contract No. F33657-69-C-0121

TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas

30 April 1970

IDENTIFICATION

AFTAC Project No.	VELA T/8706
Project Title	Development of LP Wave Discrimination Capability Using LP Strain Instruments
ARPA Order No.	624
ARPA Program Code No.	8F10
Name of Contractor	Teledyne Industries, Inc. Geotech Division
Contract No.	F33657-69-C-0121
Effective Date of Contract	1 July 1968
Amount of Contract	$503,354
Contract Expiration Date	31 August 1970
Project Manager	James E. Fix 271-2561, A/C 214

CONTENTS

i

ILLUSTRATIONS

ABSTRACT

Progress during the first three months of 1970 is reported. The mine preparation was completed by 02 February. Because of repeated delays, the mine modification subcontract was terminated before the full 40 m depth was reached. The vertical strain seismometer will be mounted in a 39-1/2 ft hole - 16 ft up and 23-1/2 ft down. The mine has been inspected and approved by the Office of the State Mine Inspector. All personnel assigned to the project assisted in the installation of the instruments which was completed in February. Preliminary recordings have led to several conclusions. The mine must be sealed to attenuate effects of air pressure fluctuations. The strain seismometers must be insulated to achieve optimum performance. A "curing time" of some duration is necessary for extreme high-magnification operation. Spurious disturbances resulting from disturbance of the mine during mine modifications and installation are decreasing with time. The noise background on the preliminary recordings is not electronic instrument noise. The strain seismographs respond well to earthquake signals.

DEVELOPMENT OF LP WAVE DISCRIMINATION CAPABILITY USING LP STRAIN INSTRUMENTS
Quarterly Report No. 7, Project VT/8706

1. INTRODUCTION

This report discusses the progress during January, February, and March, 1970, in the installation and preliminary operation of long-period (LP) strain and inertial seismographs with equivalent magnification and response characteristics. The instruments are being used to develop techniques for discrimination of LP seismic waves. The major effort on each task of the Statement of Work is discussed in separate sections. This report is to apprise the Project Office of the current status of Project VELA T/8706. It is submitted in compliance with Sequence No. A004 of the Contract Data Requirements List, Contract F33657-69-C-0121.

2. DEVELOP DESIGN SPECIFICATIONS, Task a(1)

This task has been completed.

3. DETERMINE THE MOST EFFECTIVE TECHNIQUE, Task a(2)

This task has been completed.

4. DESIGN, FABRICATE, AND TEST LABORATORY MODELS, Task b(1)

This task has been completed.

5. DEVELOP A FINAL ENGINEERING MODEL DESIGN, Task b(2)

This task has been completed.

6. DESIGN A FIELD TEST INSTALLATION, Task b(3)

This task has two parts: preparation of a suitable mine and design of the field test installation. The installation design was completed in the third quarter of FY 69. The preparation of the mine was completed on 02 February 1970.

The mining contractor repeatedly failed to fulfill his promises to supply labor to expedite completion of the full 40 m of vertical shaft. Therefore, a termination agreement was made in mid-January. A total depth of 39-1/2 feet is available for the vertical strain seismometer. Sixteen feet of this length is up and 23-1/2 feet is down. Holes have been drilled in one wall for the vertical instrument. During January, the 325 degree azimuth tunnel was cleaned out where the hoisting equipment for the winze was mounted. Two sets of parallel mounting holes were drilled in the floor of this tunnel for side-by-side comparative tests. The second set has fixed anchor points at one end of the 40 m and at 10 m from this end. There are also two possible magnet mounting points at the other end of the 40 m and in the middle. Therefore, if initial comparative tests at the 40 m length indicate testing at different length strain rods would be advisable, lengths of 10, 20, 30, or 40 m are available by moving one or both end anchors. The permanent 325 degree azimuth strain seismometer is anchored in competent rock. However, the second parallel 40 m strain seismometer is anchored in remineralized fault zones at each end.

Originally, V notches were to be blasted for recesses for the ship's doors for the air pressure seal. However, the blasting of the notches could not be properly controlled. Too light a charge would not break enough rock and a slightly heavier charge would overbreak and open up cracks. The notches were abandoned for recesses that were in the old workings at suitable points. After completion of the winze and 325 degree azimuth tunnel, the contractor removed his track, water lines, and air lines. He completed work on 02 February.

The Arizona State Mine Dust and Ventilation Engineer, representing the Office of the State Mine Inspector, made a final safety inspection of the mine on 05 February 1970. In a letter, he states: "I made a thorough examination and found everything in good order, no loose rocks, no explosives of any kind, places timbered where needed and the place cleaned out of excess rock, timber, and debris."

This task has been completed during this reporting period.

7. DESIGN, FABRICATE, AND INSTALL THE FIELD TEST INSTALLATION, Task c(1)

7.1 FABRICATE INSTRUMENTATION

The fabrication and assembly of all instrumentation is complete except for displacement transducers for the three strain seismometers.

7.2 INSTALLATION OF THE STRAIN/INERTIAL COMPLEX

The installation of the instrumentation was completed during this reporting period. During January, installation of the instrumentation was made in parallel with the mine modifications. During February, all personnel assigned to the project were at the mine to complete the installation at the earliest possible time. The three-component short-period (SP) and long-period (LP) inertial seismographs had previously been installed. The 55-degree azimuth strain seismometer, which had previously been assembled, was insulated. The 325-degree azimuth permanent strain seismometer was installed and insulated. The second 325-degree azimuth strain seismometer was installed and was operated without insulation for two weeks for comparison to an insulated seismometer. It was insulated in late March. Figure 1 was taken from near the fixed anchors of the two 325-degree azimuth strain seismometers looking toward the transducers. The permanent seismometer, on the left, has been covered with polyurethane insulation. After the picture was taken, the cracks between pieces of polyurethane and the adjustment plates were further insulated with fiberglass. The 2-inch outside diameter Invar strain rod is supported from the Invar triangle frames by three Elinvar wires. Invar was used for its low coefficient of thermal expansion and Elinvar has a low thermal coefficient of Young's modulus. The triangle frames are bolted to an Invar adjustment plate, which is tied to the rock floor by steel bolts and expansion shells. Originally, 1-foot long expansion bolts were to be used, but when the floor was drilled, it was found to be highly fractured. Therefore, 3-foot long bolts were used to attach the frames to the rock and the strain rod anchor and the magnet assemblies are tied to the rock with 6-foot long bolts.

The bottom of the gallows frame over the winze can be seen at the left of figure 1. The winze goes down 23-1/2 feet from the floor level. This length and an additional 16 feet above the floor will be used for the vertical strain seismometer after the side-by-side tests are completed. Most of the bolts for the support of the vertical seismometer have been set, so that they can stabilize with the country rock while the side-by-side tests are in progress.

Three ship's doors have been installed to provide an air seal. A 1/4-inch thick steel flange was cut to fit the opening in the rock and was welded to the door frame. After all loose rock was removed, this weldment was wedged in position and the bottom was cemented in place as shown in figure 2a. Both sides of the frame were then bricked to provide structural support and an air seal. One of the finished doors is shown in figure 2b. The full condulet shown in the figure has about 40 cables. Another 40 cables has been run in a

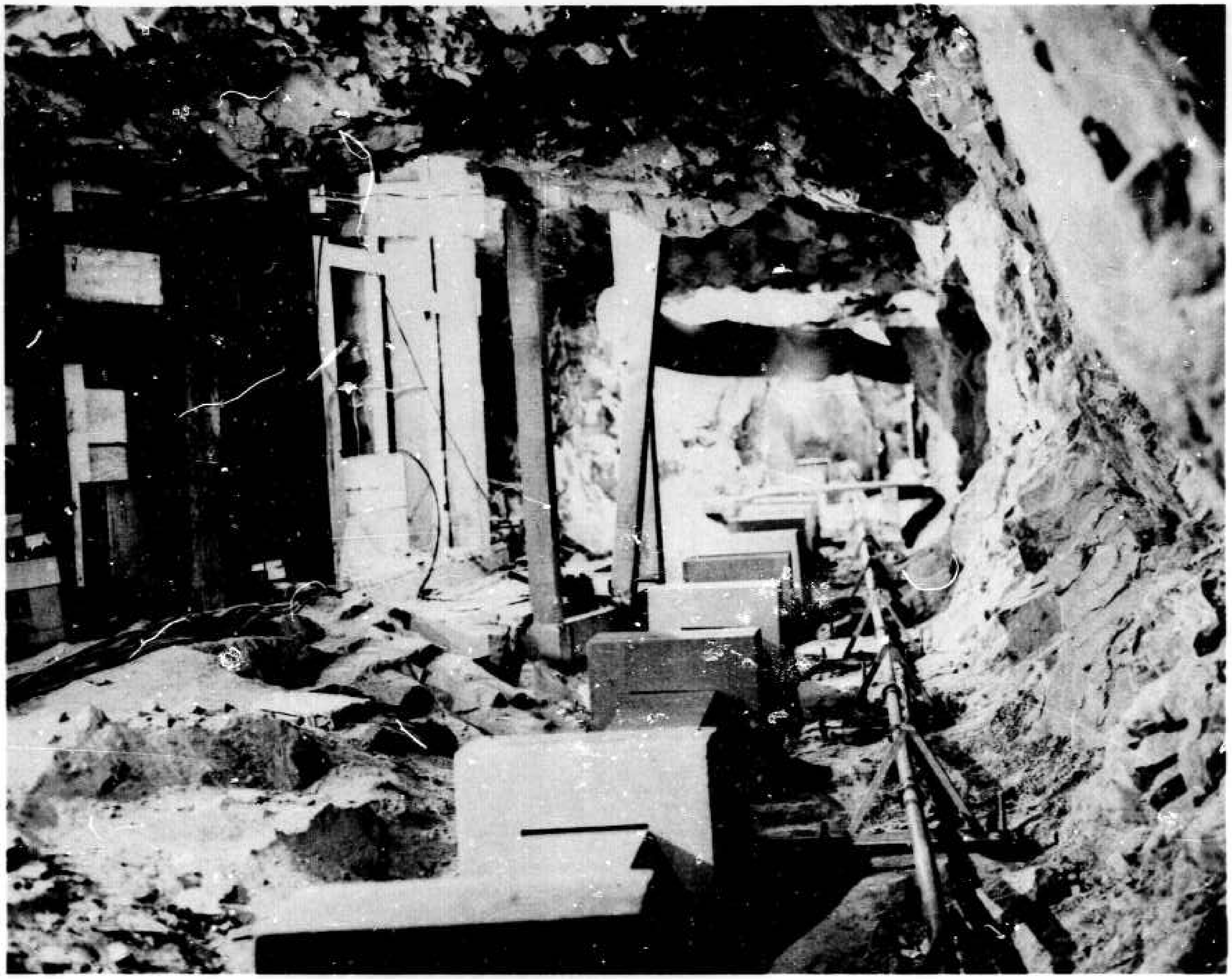
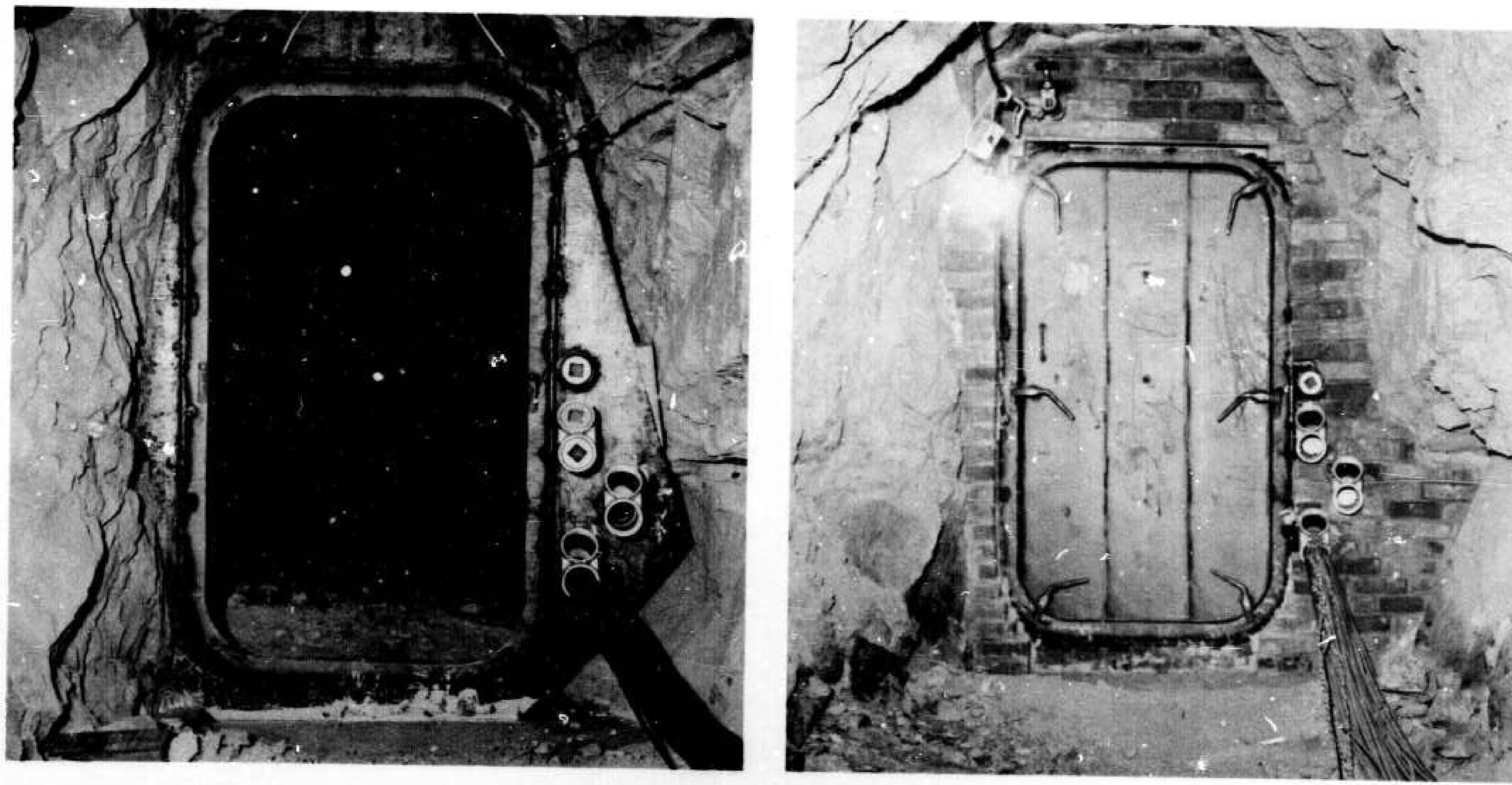


Figure 1. Side-by-side 325 degree azimuth strain seismometers. Permanent seismometer on left has been partially insulated. Vertical strain seismometer will be located at gallows frame on left of figure.

G 5551



2a. Door frame wedged into opening and cemented into the floor.

2b. Final installation

Figure 2. Ship's door installation

G 5552

second condulet. The third condulet and fourth 3-inch pipe coupling are spares. Power is in a 1-1/2-inch pipe coupling in the upper left. A second 1-1/2-inch pipe is available for pressure tests and pressure relief and/or for future power additions.

On this project, a new concept of mounting strain and LP inertial seismographs has been used with apparently excellent success. All connections of the seismometers to the native rock have been made with elastic metal in the form of expansion bolts. Previous installations have used concrete. Strain seismometer anchors have been attached to concrete piers and the strain rods have been supported from wire suspensions hung from concrete throughs or metal standards mounted in concrete piers. Inertial seismometers have been mounted on concrete piers or on the concrete bottom of a sealed metal tank. The Project VT/8706 strain seismometers are mounted with steel expansion bolts into the wall or floor of the mine. Each of the LP inertial seismometers is resting on three small steel pads screwed to the top of expansion bolts inside a metal tank.

8. CONDUCT NOISE AND STABILITY TESTS, Task c(2)

During the instrument installation, some preliminary recordings were made at night. These recordings continued to indicate that the final installation will be an outstanding seismograph station.

These preliminary recordings have led to several conclusions.

a. The mine must be sealed to attenuate effects of air pressure fluctuations. Before the ship's doors were installed, the strain and inertial seismograms were noisy with spikes and LP fluctuations. The mine was apparently flexing elastically with the pressure variations.

b. The strain pulses from the recent mining activity appeared to decrease with time.

c. Before the 55-degree azimuth and the 325-degree azimuth strain rods were insulated, but after the mine was sealed, large air convection cells within the mine caused correlated noise on both strain seismographs and on the horizontal inertial seismographs. Visual correlation did not exist after the seismometers were insulated; also, operating magnifications were increased markedly.

d. The side-by-side tests also clearly indicated that insulation is necessary. The operating magnifications on the insulated strain seismometer were more than an order of magnitude larger than those of the uninsulated seismometer.

e. A "curing time" of some duration is necessary for extreme high-magnification operation. During the last week of February, the operating magnification for the 55-degree azimuth strain seismograph with the Advanced Long-Period System (ALPS) response was able to be increased from 3.21M (3,210,00 differential pier displacement, ΔL, to film recorder at X10 view) to 63M. For a 25-sec Rayleigh wave, these magnifications are equivalent to an inertial system operating at magnifications of 8.0K (for 3.21M) and 157K (for 63M). During this same time span, the operating magnification of the 325-degree azimuth permanent strain seismograph has increased from 1.0M to 12.7M (equivalent inertial 2.5K to 31.6K). Figure 3 is a X10 view of a 16-mm film recording of calibration signals. An input ΔL between piers of 0.834 x 10^{-9}m or 2.08 x 10^{-11} strain is applied to the S55L strain seismograph and a ΔL of 4.75 x 10^{-9}m or 1.19 x 10^{-10} strain is applied to the S325L1 permanent strain seismograph.

f. The strain ALPS channel filters have the correct amplitude response. Figure 4 is a plot of the magnification response with a 6-sec notch filter of the S55L channel. The magnification plotted is recorder amplitude (at X10 view) divided by the input differential displacement between piers (ΔL). For a travelling wave with the same phase velocity at all periods, this response curve is shifted 6 dB/octave as shown in figure 5. If constant phase velocity with period is assumed, figure 5 then corresponds to the strain seismograph response to a Rayleigh wave travelling in the direction of the strain rod.

g. The strain seismographs respond well to earthquake signals. Many classical earthquake phase arrivals have been recorded. Figure 6 illustrates some arrivals on the low gain strain channels from a magnitude 6.1 event in the Aleutian Islands. All the high-gain channels are deflected off the film. The 56-sec period arrival at 1116Z on the S325LL1 trace is an excellent illustration of the classical LP arrival. Figure 7 illustrates a Rayleigh wave arrival from an event south of Honshu, Japan. Figure 8 shows a pulse of strain on both the 325-degree and 55-degree strain seismographs associated with a small local event during the continued free oscillations from the event 7-1/2h earlier illustrated in figure 6. The S325L1 seismograph indicates rock compression, and the S55L seismograph indicates rock extension.

h. The noise background on the strain seismographs is not electronic instrument noise. The S325L1 and S55L instrument noise is illustrated in figure 9. The Ithaco preamplifiers were dummy loaded, and the seismograph outputs were recorded at 6 dB and 0 dB, respectively, above operate levels.

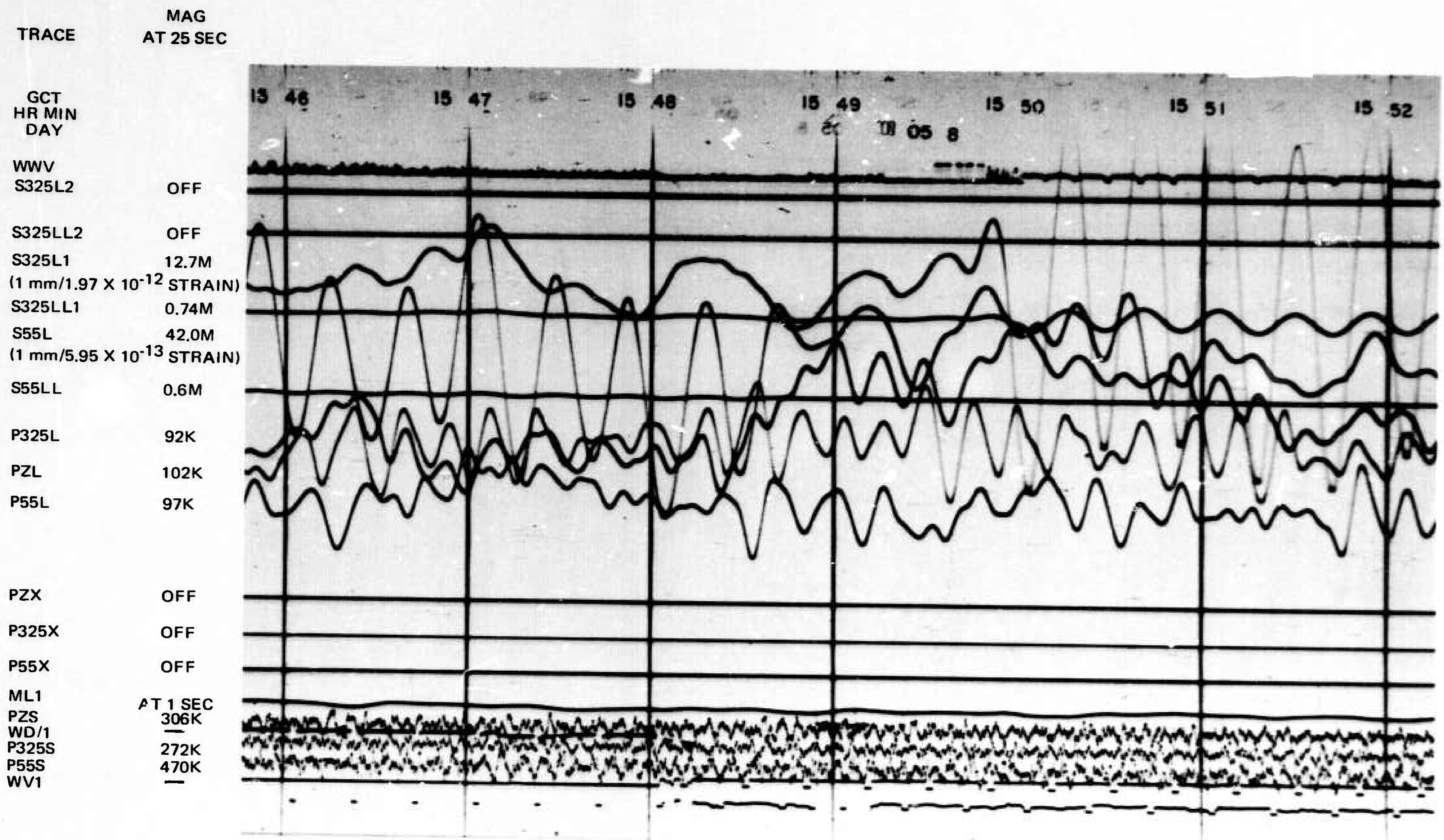


Figure 3. Calibration signals: 25 sec, S55L input is 0.834 x 10^{-9}m ΔL or 2.08 x 10-11 strain, S325L1 input is 4.75 x 10^{-9}m ΔL or 1.19 x 10^{-10} strain.

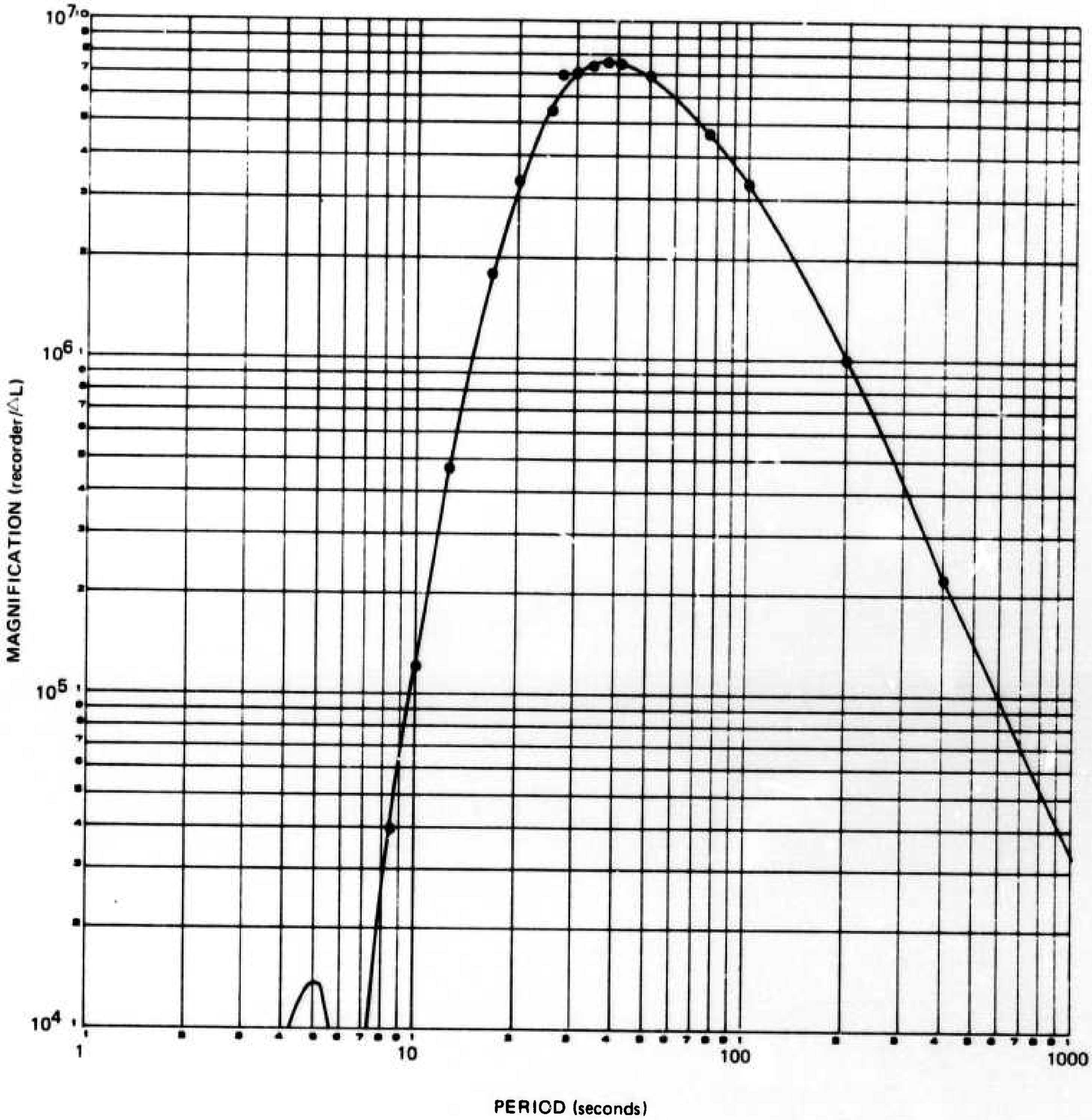


Figure 4. Amplitude response S55L, advanced long-period system response with 6-sec notch filter. Magnification is recorder amplitude divided by differential pier motion.

G 5553

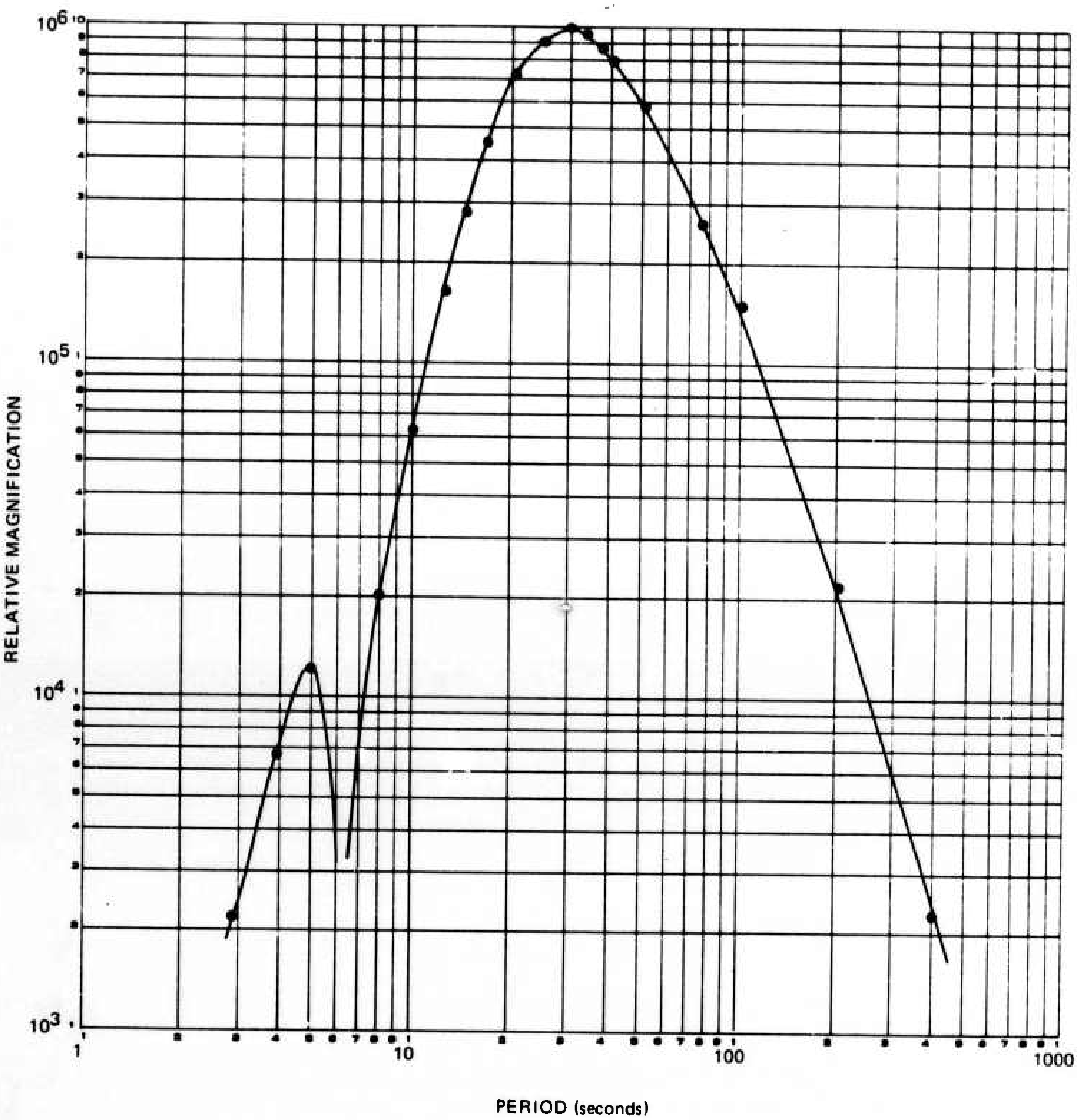


Figure 5. Relative amplitude response of S55L strain seismograph to a travelling wave with the same phase velocity at all periods.

G 5554

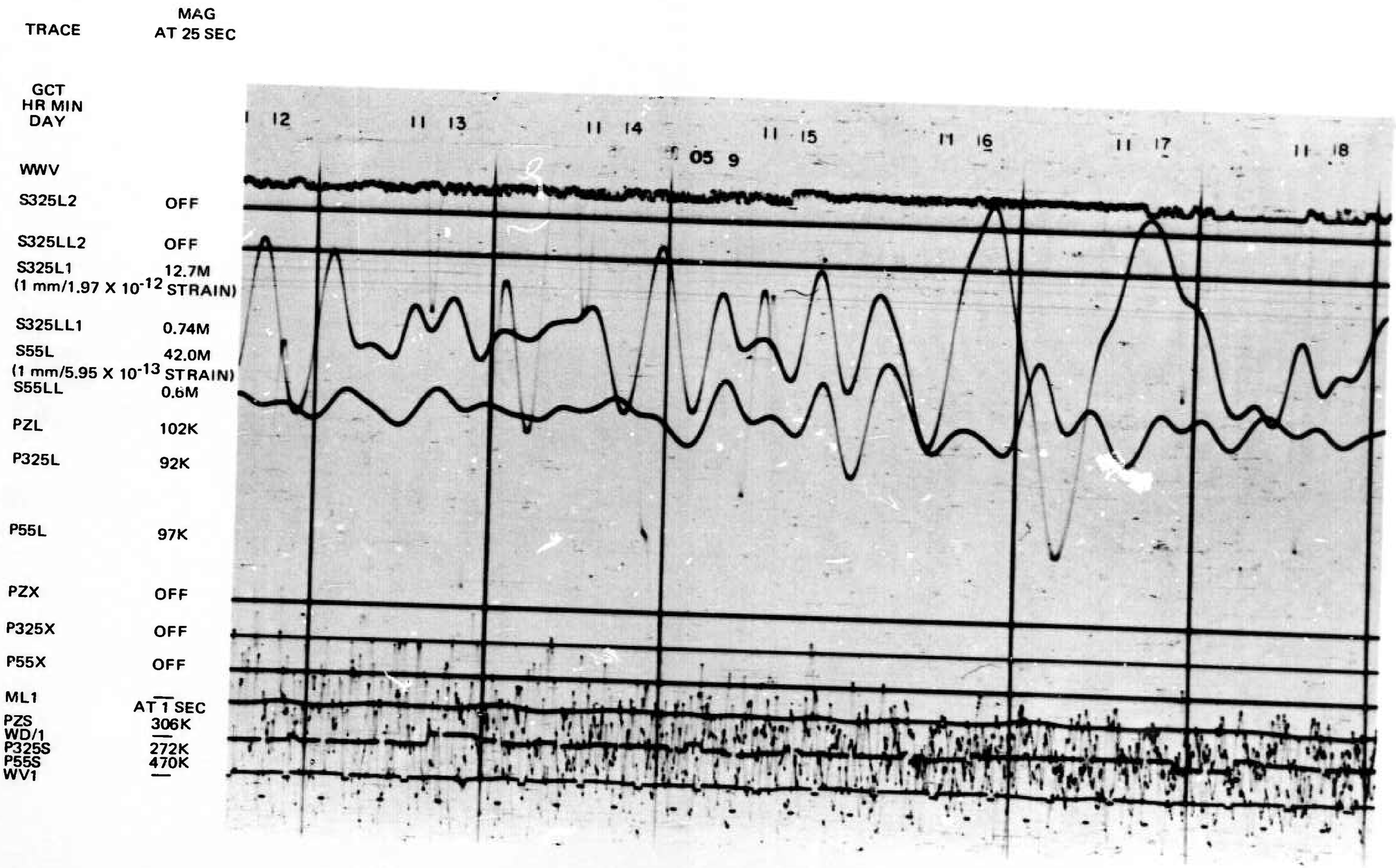


Figure 6. Reproduction of a 16-mm film record of earthquake phase arrivals. USC&GS PDE epicenter data: Andreanof Islands, Aleutian Islands, m_b = 6.1, 0 = 1052:31.2, 52.7N, 175.1W, h = 162 km, $\Delta \approx$ 48 deg. (Note: Time lines 18 sec late) Arrivals: SS at 1111:52, sSS at 1112:48, SSS at 1113:55, sSSS(?) at 1115:05, SSSS(??) at 1115:58.5.

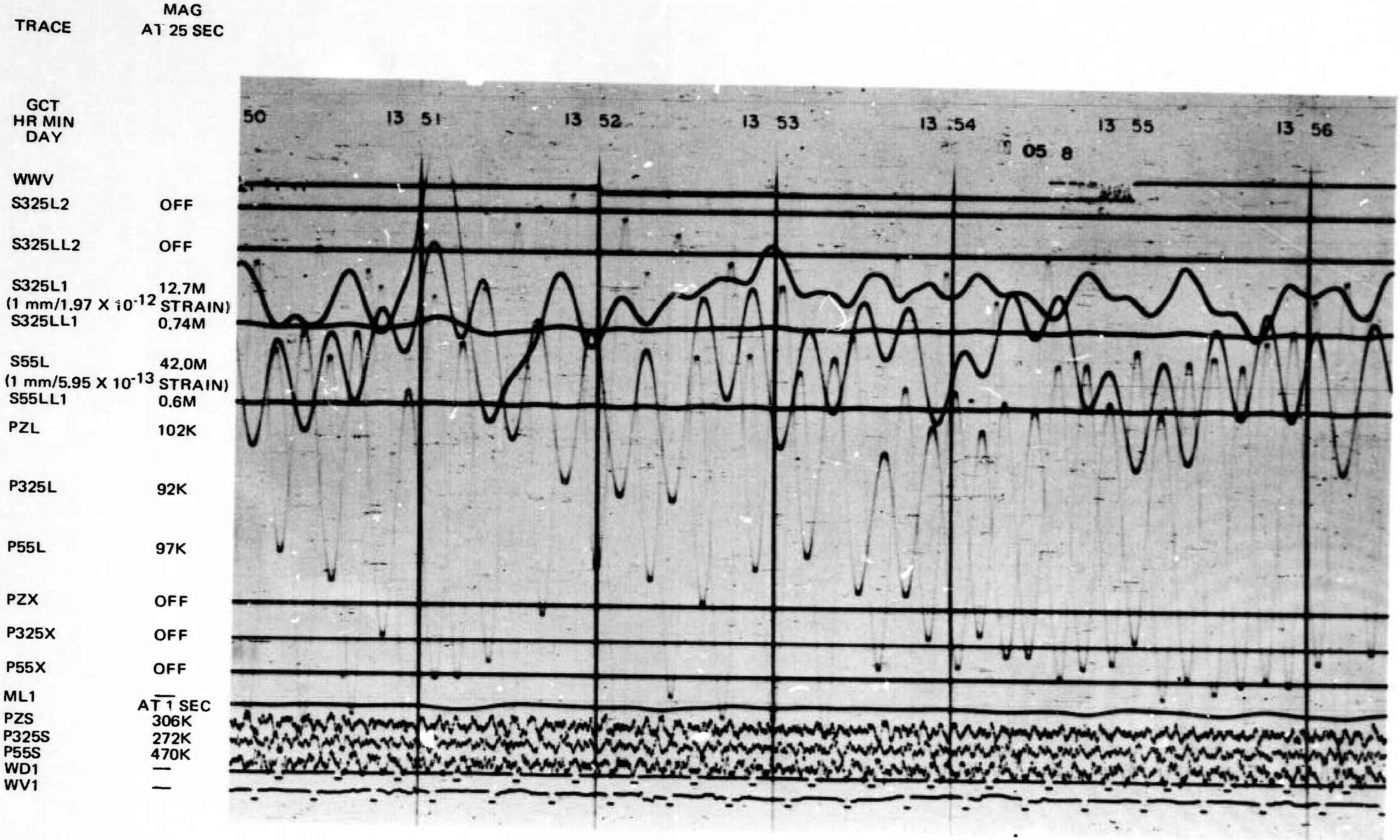


Figure 7. Reproduction of a 16-mm film record of Rayleigh wave arrival from event S of Honshu, Japan. USC&GS PDE epicenter data: $m_b = 5.1$, 0 = 1259:57.1, 31.8N, 141.6E, h = 13 km, $\Delta \approx 86$ deg.

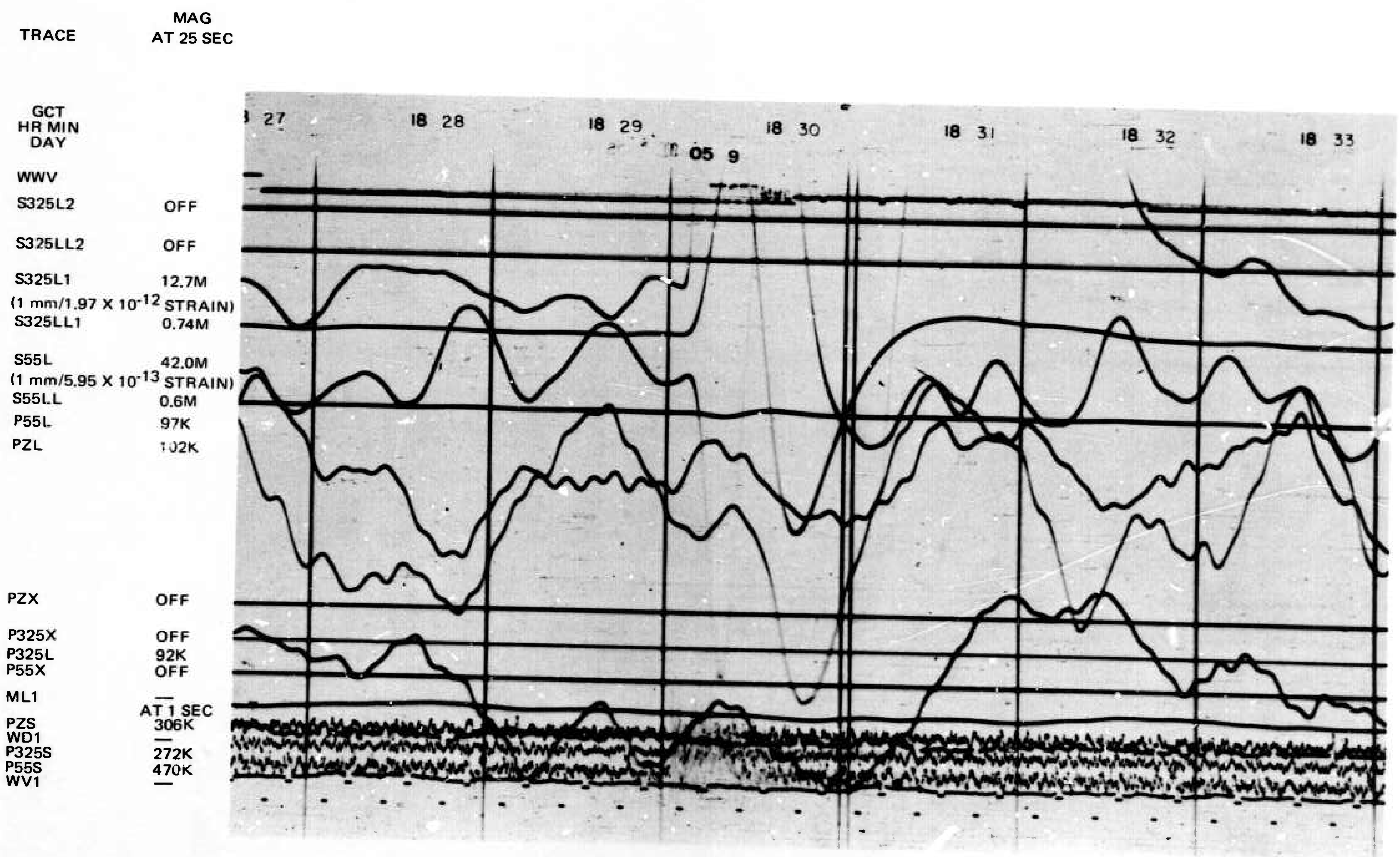


Figure 8. Pulse of strain recorded on perpendicular horizontal strain seismographs associated with a local event. Long-period excursions are free oscillations from an event 7-1/2 h earlier.

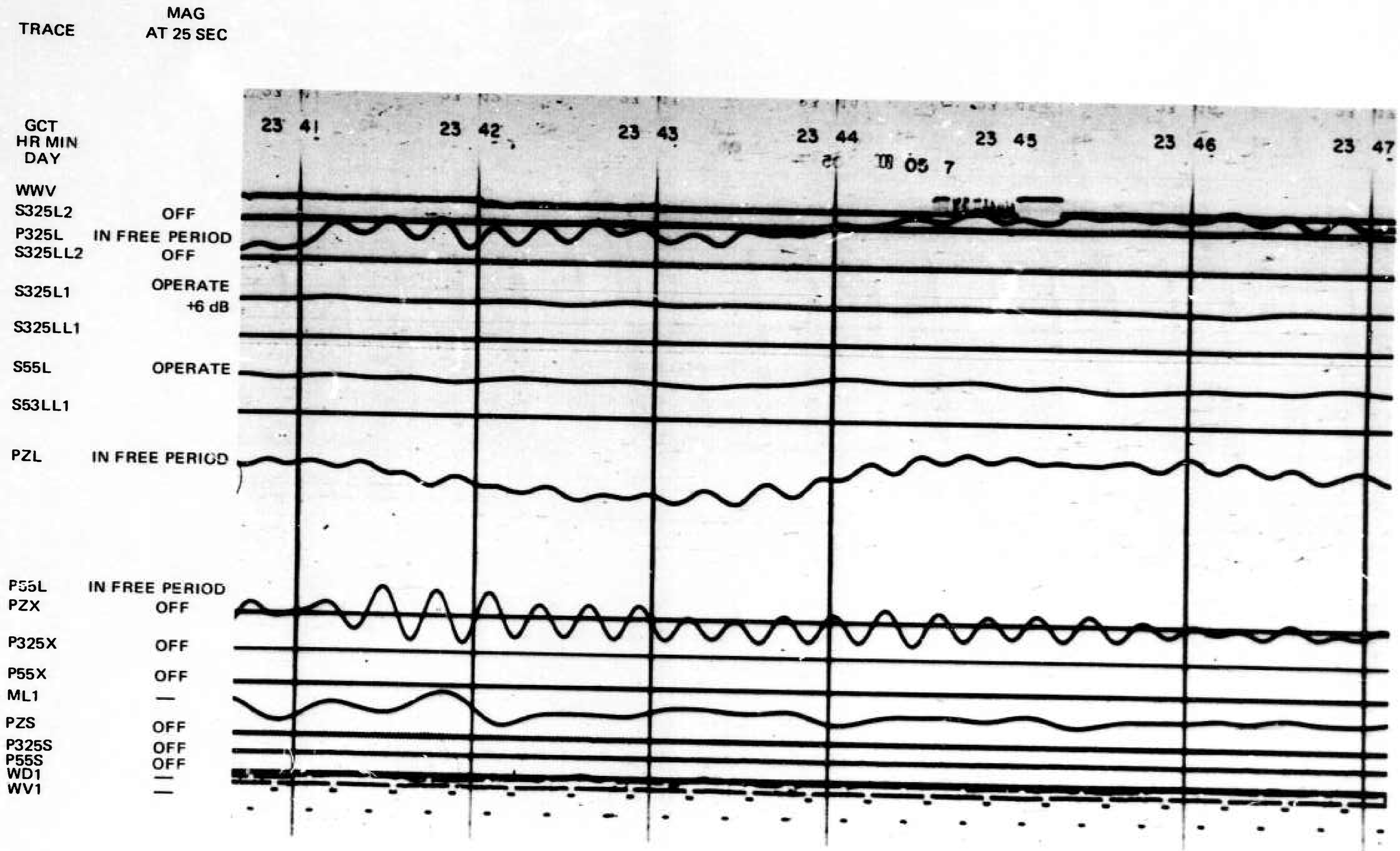


Figure 9. Strain seismograph instrument noise recorded at 6 dB above operate level on S325L1 and at operate level on S55L.

9. CONDUCT PRELIMINARY OPERATION AND EVALUATE INSTRUMENT PERFORMANCE, Task c(3)

Some preliminary operation was possible during the mine preparation when the mine ventilation blowers were not needed and during the instrument installation at night when personnel were not working inside the mine.

An early recording of a South Pacific earthquake illustrates some of the capabilities of the system. At the time of this recording, the mine was not sealed, only the 55-degree azimuth strain seismometer was installed, and none of the instruments were insulated. The earthquake occurred on 06 January 1970 and was designated a magnitude 5.4 on the LASA preliminary epicenter data. The LASA epicenter is at a 272-degree azimuth from QC-AZ. Figure 10 shows the P-wave arrival at 0549:48.5 on the vertical inertial seismographs with no significant motion recorded on the horizontal strain. The PP wave arrived at 0554:00 with a small enhancement on the difference trace. In figure 11, the S wave arrived at 0600:35 with an enhanced small SH arrival on the sum trace and some cancellation on the difference trace. The S wave is followed by shear coupled PL to about 0604. At 0603:00, the PPS phase arrives as SV motion as seen on the difference trace. In figure 12, sSS arrived 0604:40.8 as an SV wave on the difference trace and SSS arrived at 0612:18 as an SH wave on the sum trace. In figure 13, the LR1 Rayleigh wave had driven all LP traces off the film except the sum trace, which shows cancellation compared to the S55L, P55L, and the difference trace. The LR2 Rayleigh wave from the major arc arriving from the opposite azimuth is enhanced on the sum trace and is cancelled on the difference trace in figure 14. This one earthquake illustrates some of the capability of this high sensitivity strain/inertial complex.

10. OPERATE THE STRAIN-INERTIAL SYSTEM, Task d(1)

No effort was devoted to this task during this reporting period.

11. DEVELOP METHODS OF WAVE DISCRIMINATION, Task d(2)

No effort was devoted to this task during this reporting period.

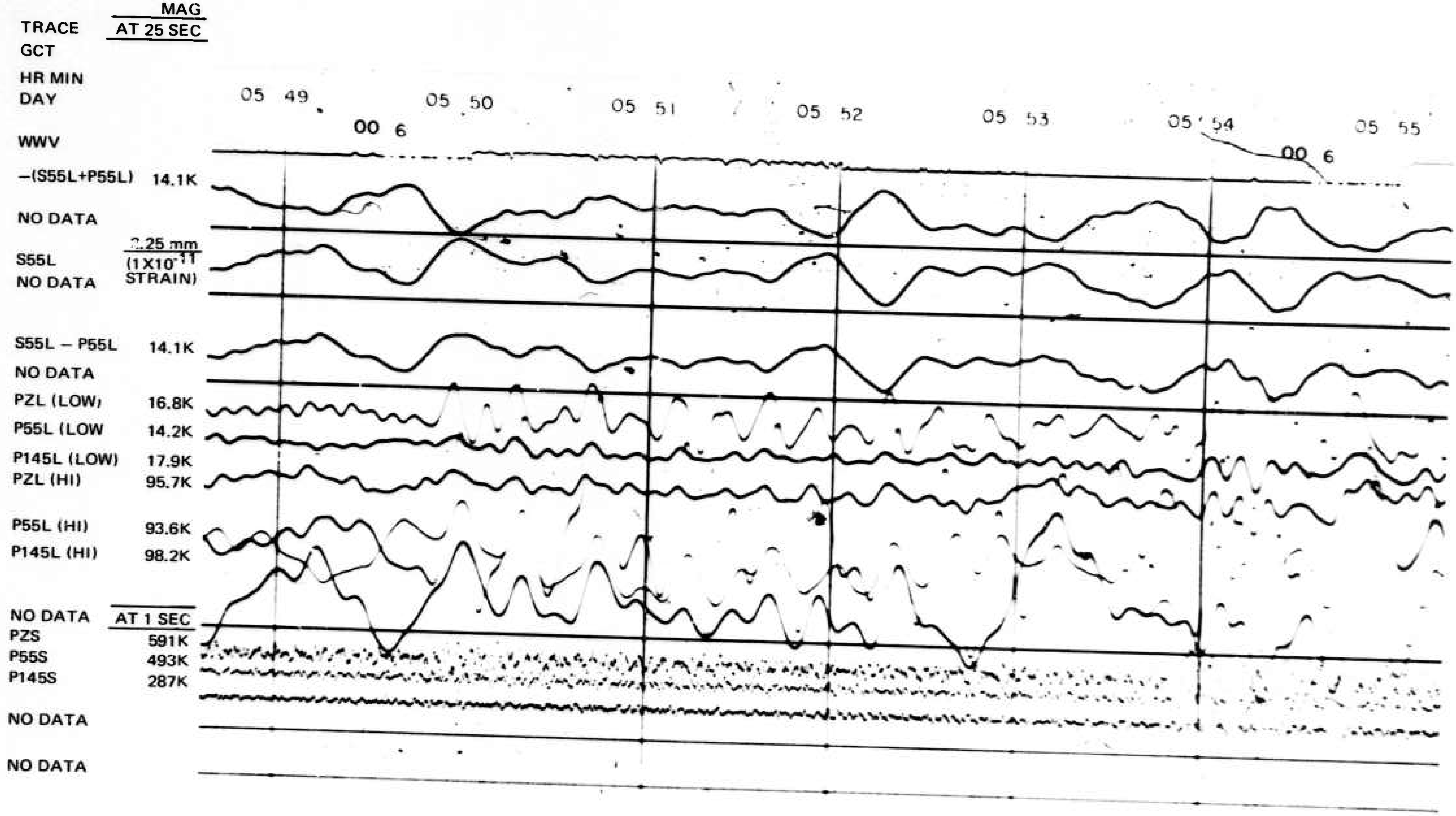


Figure 10. Reproduction of a 16-mm film record showing arrival of P at 0549:48.5 and PP at 0554:00 from an earthquake in the Caroline Islands Region. LASA preliminary data: m_b = 5.4, O=0536:57, 2.4 N, 158.3 E, h = 33 km, Δ = 89 deg, 272 deg azimuth.

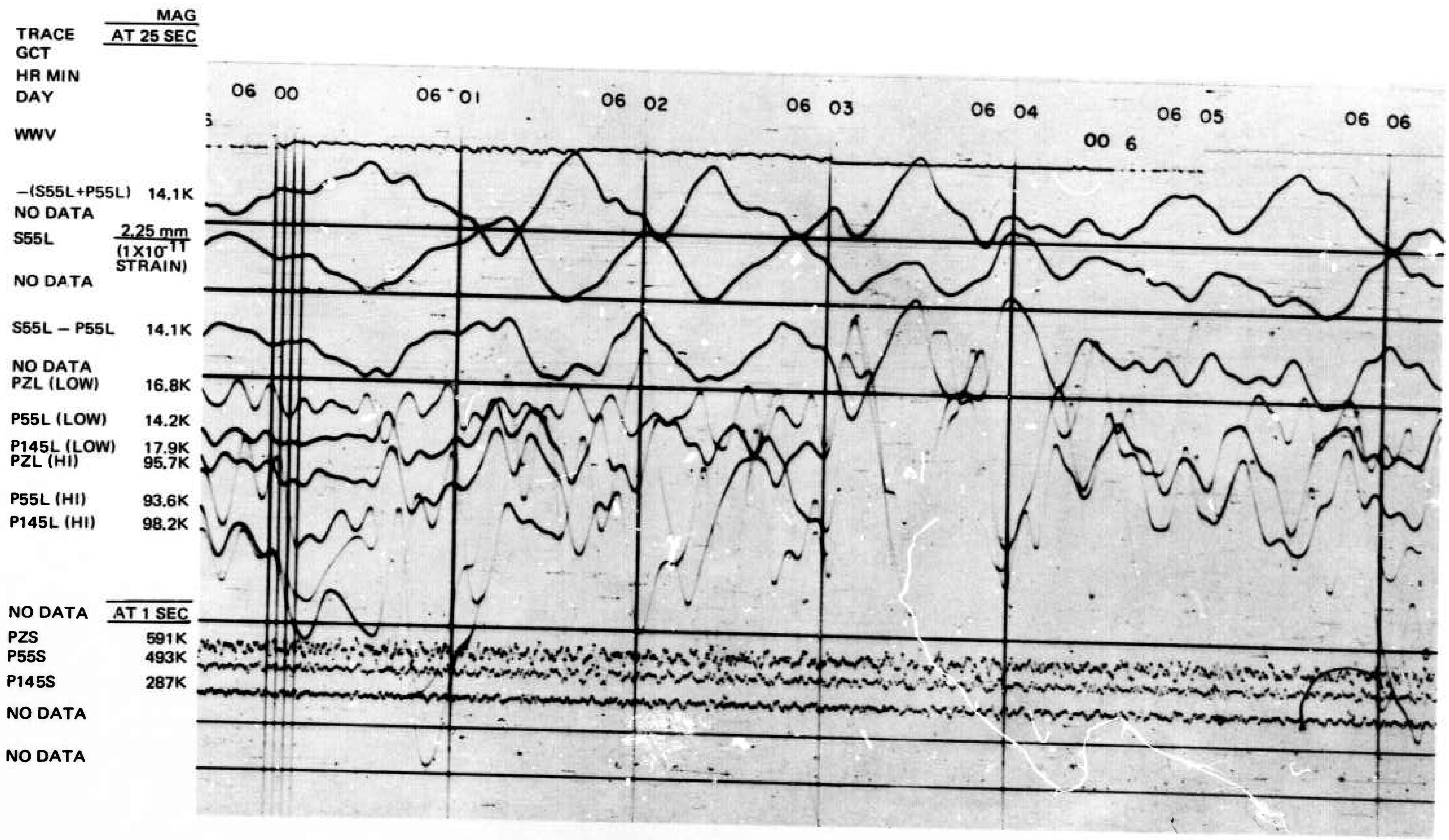


Figure 11. Reproduction of a 16-mm film record showing arrival of S (SH) at 0600:35, of PL at 0601-0604, and of PPS (SV) at 0603:00 from an earthquake in the Caroline Islands Region. LASA preliminary data: m_b = 5.4, 0 = 0536:57, 2.4 N, 158.3 E, h = 33 km, Δ = 89 deg, 272 deg azimuth.

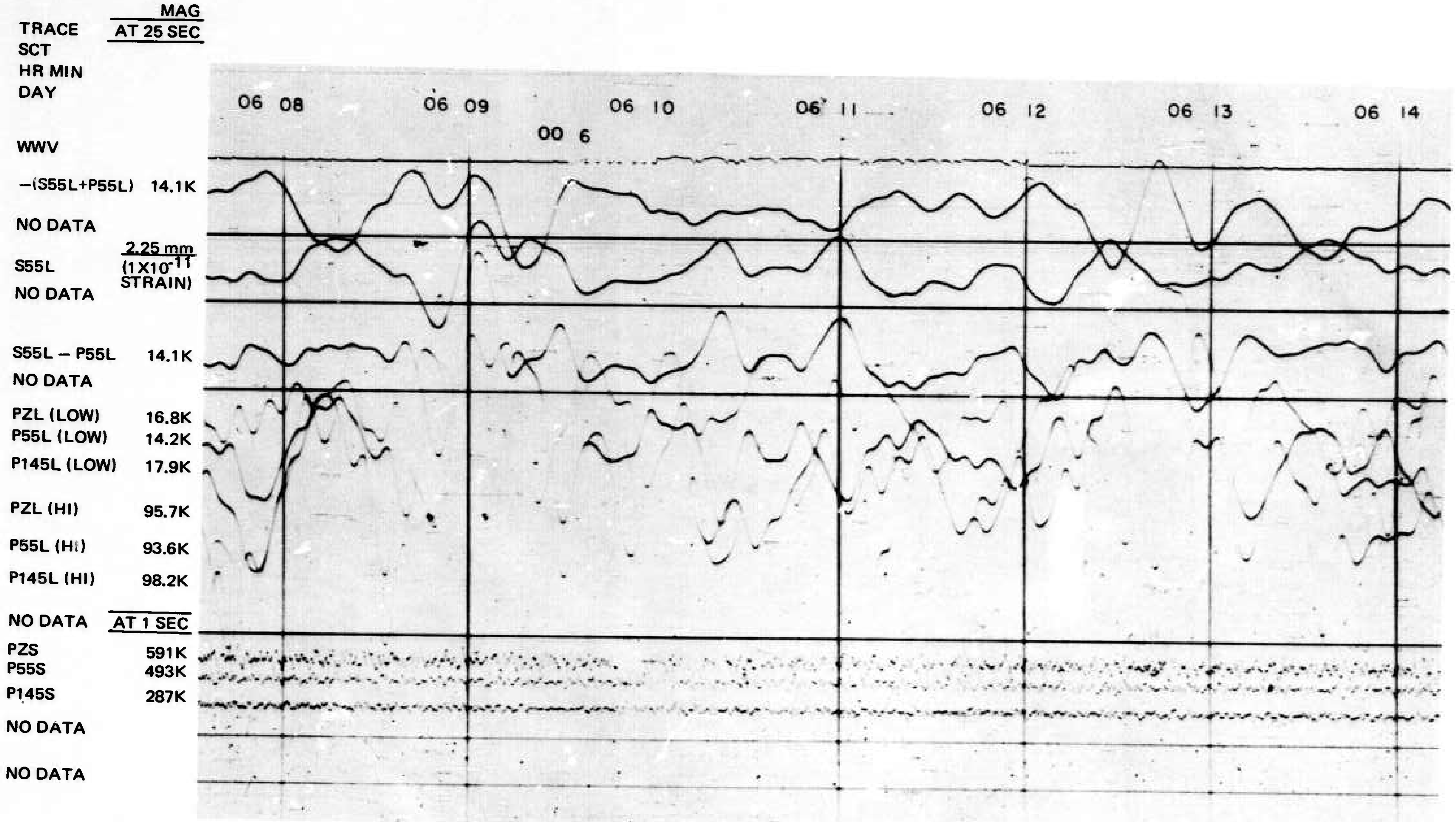


Figure 12. Reproduction of a 16-mm film record showing arrival of sSS (SV) at 0603:41 and SSS (SH) at 0612:18 from an earthquake in the Caroline Islands Region. LASA preliminary data: $m_b = 5.4$, 0 = 0536:57, 2.4 N, 158.3 E, h = 33 km, Δ = 89 deg, 272 deg azimuth.

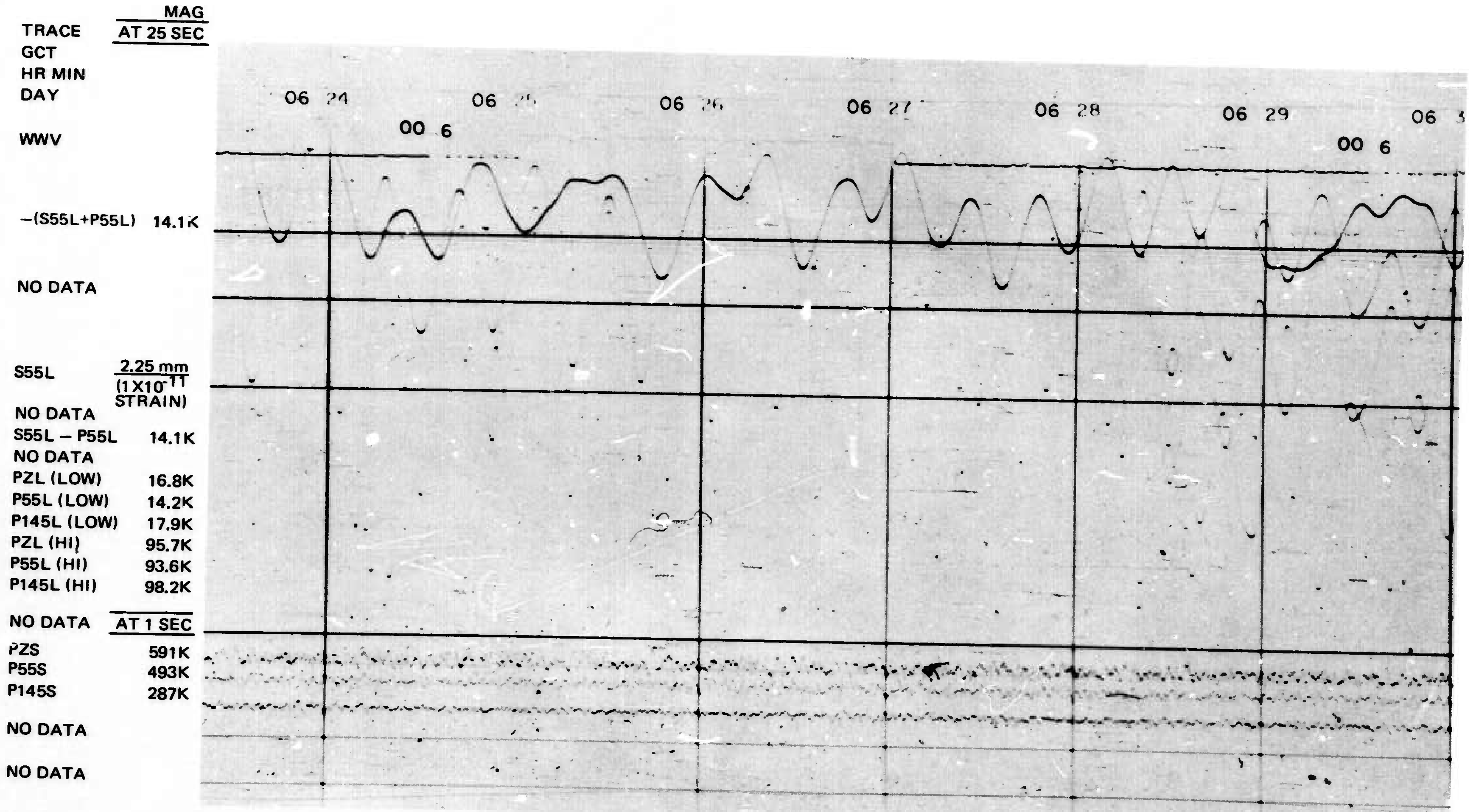


Figure 13. Reproduction of a 16-mm film record showing LR1 Rayleigh wave enhancement on difference trace and cancellation on sum trace from an earthquake in the Caroline Islands Region. LASA preliminary data: m_b = 5.4, 0 = 0536:57, 2.4 N, 158.3 E, h = 33 km, Δ = 89 deg, 272 deg azimuth.

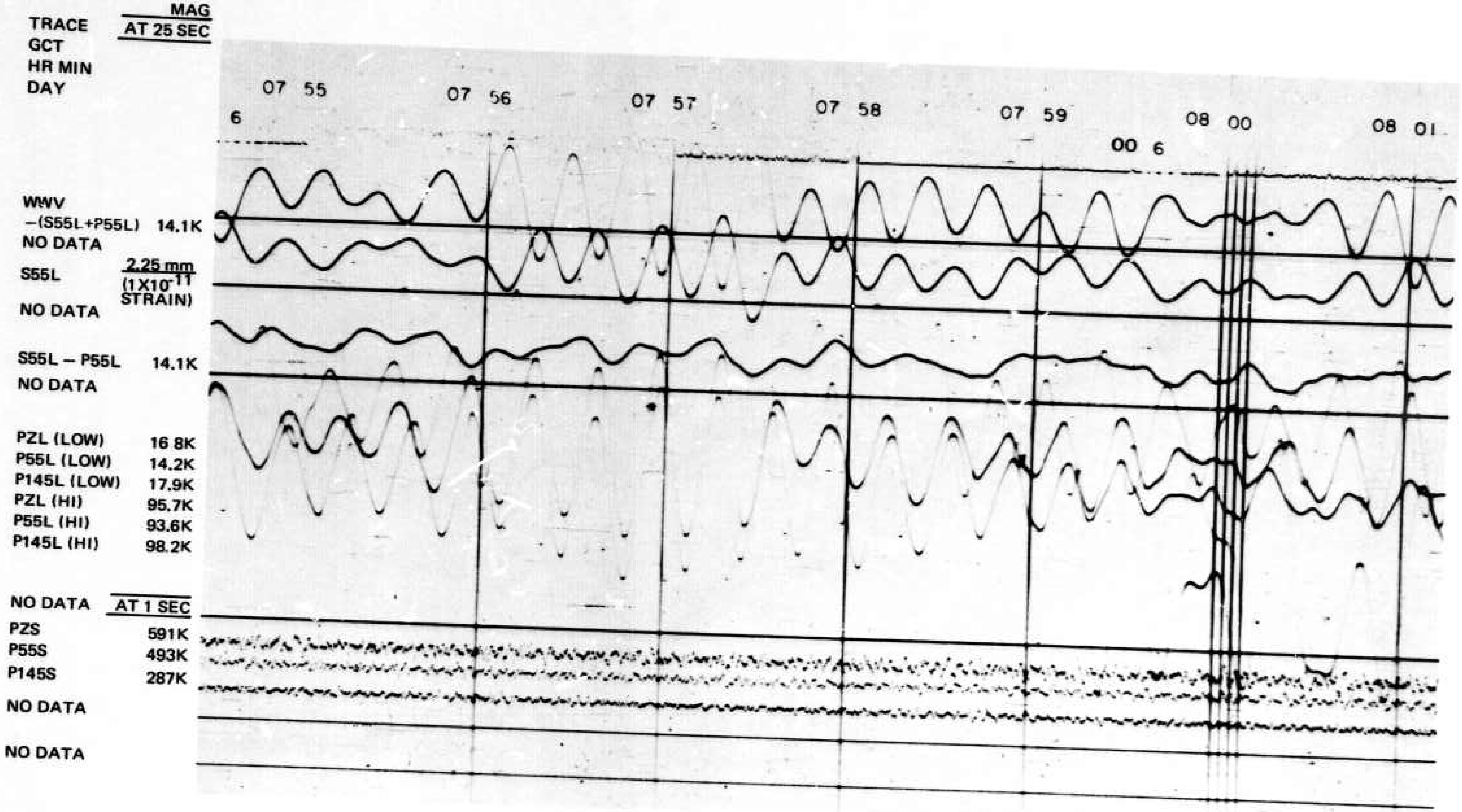


Figure 14. Reproduction of a 16-mm film record showing LR2 Rayleigh wave enhancement on sum trace and cancellation on difference trace from an earthquake in the Caroline Islands Region. LASA preliminary data: $m_b = 5.4$, 0 = 0536:57, 2.4 N, 158.3 E, h = 33 km, Δ = 89 deg, 272 deg azimuth.

12. SPECIAL REPORT

A special technical report (Fix and Sherwin, 1970 a, b) has been submitted to summarize the instrumentation complex objectives, design, installation and preliminary results. After receiving authority for publication according to the VELA UNIFORM security review procedure, a paper was presented at the National Meeting of the American Geophysical Union based upon this report.

13. REFERENCES

Fix, James E. and Sherwin, John R., 1970a, A high-sensitivity strain/inertial seismograph installation, Technical Report No. 70-3: Garland, Teledyne Geotech, 44 p.

Fix, James E. and Sherwin, John R., 1970b, A high-sensitivity strain/inertial seismograph installation (abstract): EOS, Trans. Amer. Geohpys. Union, v. 51, No. 6, p. 364-365.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Teledyne Industries, Inc., Geotech Division 3401 Shiloh Road - Garland, Texas 75040	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

3. REPORT TITLE

Development of LP Wave Discrimination Capability Using LP Strain Instruments Quarterly Report No. 7, Project VT/8706

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Quarterly Report, 1 January 1970 to 31 March 1970

5. AUTHOR(S) (First name, middle initial, last name)

Fix, James E.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
30 April 1970	27	2

8a. CONTRACT OR GRANT NO. F33657-69-C-0121	9a. ORIGINATOR'S REPORT NUMBER(S) TR 70-17
b. PROJECT NO. VELA T/8706	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT This document is subject to special export controls and each transmittal to a foreign government or foreign national may be made only with the prior approval of Chief, AFTAC. Qualified users may request copies of this document from: Defense Documentation Center, Cameron Station, Alexandria, Va. 22314

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	HQ USAF (AFTAC/VELA Seismological Center), Washington, D. C. 20333

13. ABSTRACT

Progress during the first three months of 1970 is reported. The mine preparation was completed by 02 February. Because of repeated delays, the mine modification subcontract was terminated before the full 40 m depth was reached. The vertical strain seismometer will be mounted in a 39-1/2 ft hole - 16 ft up and 23-1/2 ft down. The mine has been inspected and approved by the Office of the State Mine Inspector. All personnel assigned to the project assisted in the installation of the instruments which was completed in February. Preliminary recordings have led to several conclusions. The mine must be sealed to attenuate effects of air pressure fluctuations. The strain seismometers must be insulated to achieve optimum performance. A "curing time" of some duration is necessary for extreme high-magnification operation. Spurious disturbances resulting from disturbance of the mine during mine modifications and installation are decreasing with time. The noise background on the preliminary recordings is not electronic instrument noise. The strain seismographs respond well to earthquake signals.

DD FORM 1 NOV 65 1473

Unclassified
Security Classification

Unclassified
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Long-period strain seismograph						
Seismology						
Strain instruments						
Wave discrimination						

Unclassified
Security Classification